


Note		
	OBJET (Subject) : REPORT OF THE TESTS PERFORMED ON THE 50 + 200 FIRST DPDs AT SACLAY	Ref : SED-GLAST-N-5300-121-PA
		GLAST Ref : LAT-TD-00444-02
		Pages : 1/18
		Date : 22/10/01

Destinataires (To) : The LAT collaborators

Pour information (Copy) : Ph.Mangeot

These tests have been conducted and done by:

C. Bondel, Ph.Bourgeois , R. Granelli, C.Jeanney, Y.Piret, P. Prat, L. Minchella (ATERMES).

Change History log

	30/11/01	Correction J.Cretolle				
Draft	26/11/01		Ph.Bourgeois			
Ind.	Date	Modifications	Visa Auteur	Visa RAQ	Visa Vérificateur	Visa Approb.

Table of content

1	INTRODUCTION	3
1.1	PURPOSE	3
1.2	DEFINITION	3
1.2.1	Acronyms	3
1.2.2	Definitions	3
1.3	APPLICABLE DOCUMENTS	3
1.4	REFERENCE DOCUMENTS	3
2	STATISTICS ON HAMAMATSU MEASUREMENTS	4
3	TEST ON THE 50 NRL DPDS (AT CEA)	5
3.1	MECHANICAL TEST	5
3.1.1	Dimensions	5
3.1.2	Flatness	6
3.1.3	Visual inspection	8
3.2	ELECTRICAL TEST	10
4	TEST ON THE 200 CEA DPDS	12
4.1	MECHANICAL TEST	12
4.1.1	Dimensions	12
4.1.2	Trapezoid shape	13
4.2	ELECTRICAL TEST	13
5	TEST WITH THE KAPTON FLEX	16
6	CONCLUSION	17



1 Introduction

1.1 Purpose

This document summarizes mostly the measurements done on the first 50 Dual PIN photoDiodes (DPD) ordered by NRL following by those performed on the 200 DPDs ordered by CEA with the same Specification (LAT-DS-00072-03).

These measurements, previously described in the note Dual PIN photoDiodes Test Plan (LAT-SS-00391-01), are acceptance tests with the aim to learn about the characteristics of the Hamamatsu DPDs, to upgrade the flight DPDs specification and to prepare and finalize their future acceptance tests.

We give statistics on the Hamamatsu data (capacitance, dark current and sensitivity).

We present our results of:

- Electrical measurements: capacitance and dark current, on both PIN photodiodes,
- Mechanical measurements: length , width, thickness , position of the connection pins, and flatness of the input window.
- Electrical measurements at the different levels of the kapton flex welding.

1.2 Definition

1.2.1 Acronyms

GLAST	Gamma-Ray Large Area Telescope
LAT	Large Area Telescope
CAL	the Calorimeter subsystem of the LAT
DPD	Dual PIN photoDiode
NRL	Naval Research Laboratory (Washington, USA)
CEA	Commissariat à l'Energie Atomique (Saclay, France)

1.2.2 Definitions

°C	degree Celsius
µm	micrometer
mm	millimeter
cm	centimeter
pF	pico Farad (10^{-12})
nA	nano ampere (10^{-9})
rms	root mean square

1.3 Applicable documents

Documents that are relevant to the development of the GLAST LAT and its requirements include the following:

LAT-DS-00072-03	' Specification for the Calorimeter PIN Photodiode Assembly', 20 February 2001
-----------------	--

1.4 Reference documents

LAT-SS-00391-01	Dual PIN photoDiodes Test Plan,
SED-GLAST-Y-5300-129-PB	Procédure de mesure des caractéristiques électriques des DPDs
CF-GLAST-N-5400-33-PM	CDE Kapton cable dimensions and definition

2 Statistics on Hamamatsu measurements

The manufacturer, Hamamatsu have done measurements on each PIN diodes (A & B) of each DPDs: capacitance, dark currents and sensitivity at 540nm. All the measurements have been done with a bias Voltage of 70V, and the capacitance has been measured at 1MHz. We have first received the data on data sheet, then in a file attached to an e-mail. We have transferred the data to an excel file and make statistics.

The statistics have been done on the data from the 300 DPDs ordered by the Glast collaboration (100 by NRL and 200 by CEA).

- Dark Current:

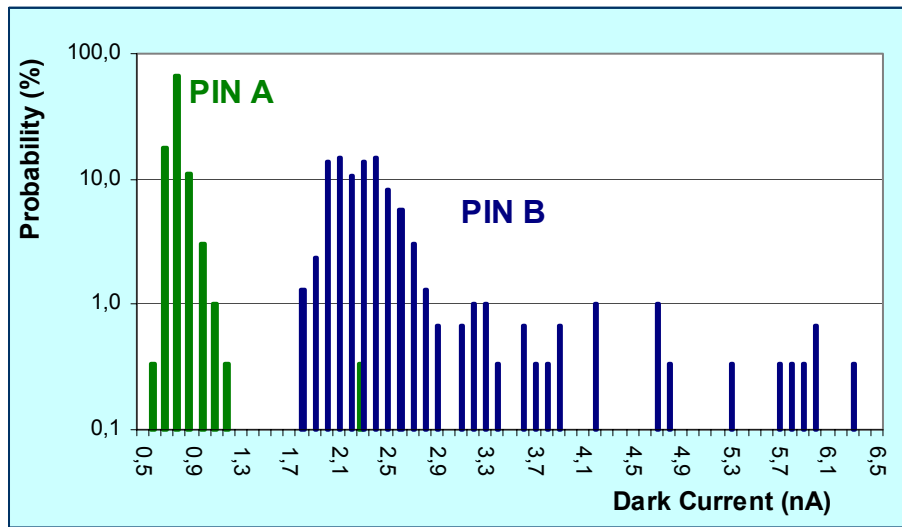


Fig . 1: Statistics on the Dark Current

We can see a tail on the distribution of the D.C. of the PIN B (8%, between 3 and 6.3nA), we plan to do extensive tests on these DPDs (part of them will be selected for the technologic evaluation in SERMA). There is only one PIN A with an atypical D.C. (0.3%, at 2.3nA).

- Capacitance:

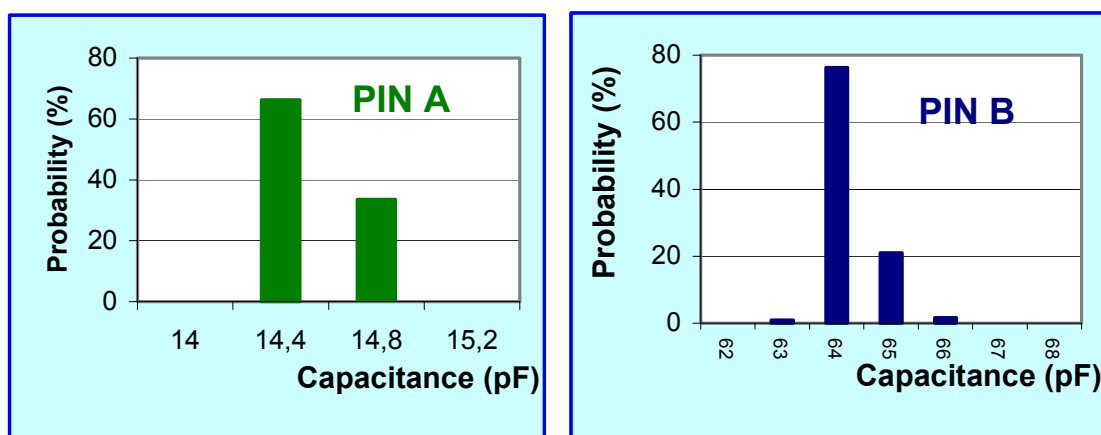


Fig . 2: Statistics on the capacitance

The capacitance distributions are very narrow both for PIN A and B. We have only to note that the PIN B typical value is greater than specified (14.5 instead of 10pF). Hamamatsu has explained this discrepancy with the calculated value used for the specification by the unusual narrow shape of the PIN B (10.5x2.4mm²). The collaboration has accepted this difference and the specification will take into account

this new typical value. The impact of this capacitance increase could be on noise of the front-end preamplifier.

- Sensitivity:

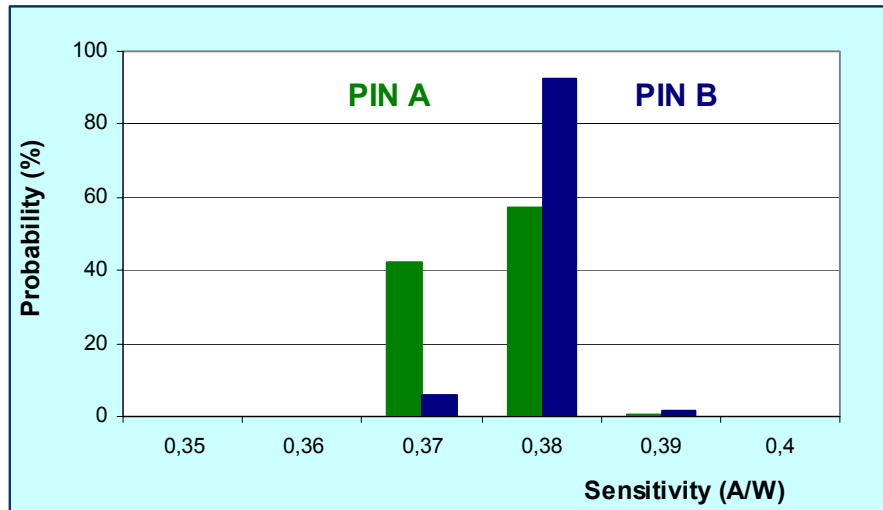


Fig . 3: Statistics on the sensitivity

The sensitivity distributions are also very similar and narrow. This parameter is as expected, independent of the PIN size.

	Dark Current (nA)		Capacitance (pF)		Sensitivity (W/A)	
	PIN A	PIN B	PIN A	PIN B	PIN A	PIN B
Specif	1.0	3.0	10.0	65	0.37	0.37
Mean	0,81	2,46	14,50	64,23	0,38	0,38
rms	0,11	0,71	0,14	0,48	0,01	0,003
Max.	2,30	6,30	14,90	66,00	0,39	0,39
Min.	0,63	1,80	14,40	63,00	0,37	0,37

Table 1: Statistic summaries.

In the following we will compare our capacitance and D.C. results with these Hamamatsu ones

3 Test on the 50 NRL DPDs (At CEA)

The NRL have given to us 50 of their 100 DPDs to equip VM2 Xtals and to begin the DPD training tests. We have done extensive test on them, and begin the debugging of our serial electrical test procedure.

3.1 Mechanical test

3.1.1 Dimensions

We have measured the size (Length, width and thickness) of all DPDs with a digital gauge (0.01mm accuracy).

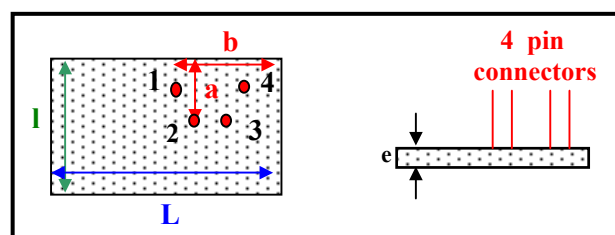


Fig . 4: Measurements schema

With a binocular microscope associated with a micrometer, we have also measured the position of the 4 pin connectors.

The following table resume our measurements. The mean values are very close to the specification and the accuracy better than $\pm 200\mu\text{m}$ as specified even if you look at the max-min values. As the more difficult to measure has been the pin connectors positions and their relative positions are more reproducible, we have decided to check only the position of pin #4, for our next 200 DPDs.

	Sizes			4 pin connector positions							
	L	I	e	a1	a2	a3	a4	b1	b2	b3	b4
Specif. (mm)	22,30	15,00	1,78	8,75	6,75	3,75	1,75	2,55	4,55	4,55	2,55
Average (mm)	22,31	15,02	1,78	8,64	6,67	3,71	1,72	2,58	4,55	4,56	2,58
min (mm)	22,28	14,99	1,72	8,50	6,50	3,60	1,65	2,50	4,40	4,45	2,45
max (mm)	22,41	15,07	1,82	8,80	6,80	3,85	1,90	2,70	4,65	4,70	2,65
max-min (μm)	130	80	100	300	300	250	250	200	250	250	200
rms (μm)	18	18	22	57	62	43	51	51	58	56	55

Table 2: Summaries of the mechanical measurements of the 50 NRL DPDs.

3.1.2 Flatness

For the flatness and the epoxy thickness, we have used a non-contact, automated dimensional metrology system (V6x12 from General Scanning Inc.) already experimented in the MEGACAM project. The optical lens used is a 20x SLWD Mitutoyo, its depth of focus is $3.51\mu\text{m}$ but thanks to the software we could reach an accuracy of about $\pm 2\mu\text{m}$.

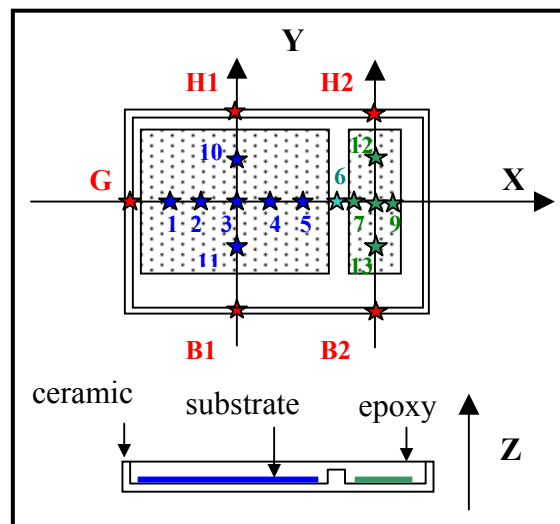


Fig . 5: Measurements schema

Figure 5 show the positions where we have done the different measurements. At the level of the PIN diodes A (7 to 9 , 12 and 13) and B (1 to 5 , 10 and 11) we have focused both on the epoxy and on the substrate (the silicon) which allow us to extract the epoxy thickness. The position #6 is only at the epoxy level and the positions G, H1 ,H2 , B1 and B2 are at the level of the carrier (ceramic).

As we do not know the absolute planar position of the DPD, to calculate the flatness we have fitted a plane with the 18 positions of measurement then and extracted the flatness regard to this plane. We have take a sample of 15 DPDs (5mn of measurement by DPDs).

The figure 6 show an example of flatness calculation and the table 3 summaries the results which are very good.

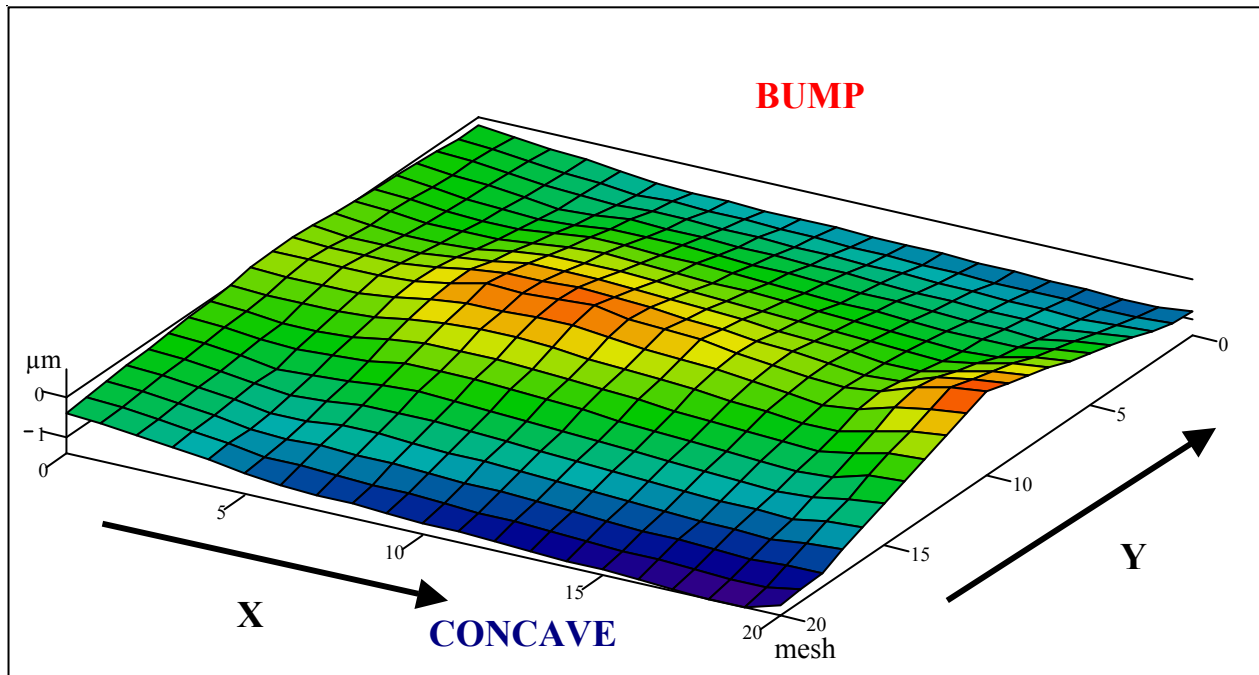


Fig . 6: Flatness view of the DPD #100

Flatness (μm)	
Specification	2,00
Mean	0,61
min	1,00
max	0,30
max-min	0,70
rms	0,22

Table 3: Summaries of the flatness calculation on 15 of the NRL DPDs.

The figure 7 to 9 give the epoxy thickness measurements of 10 of the 15 DPDs:

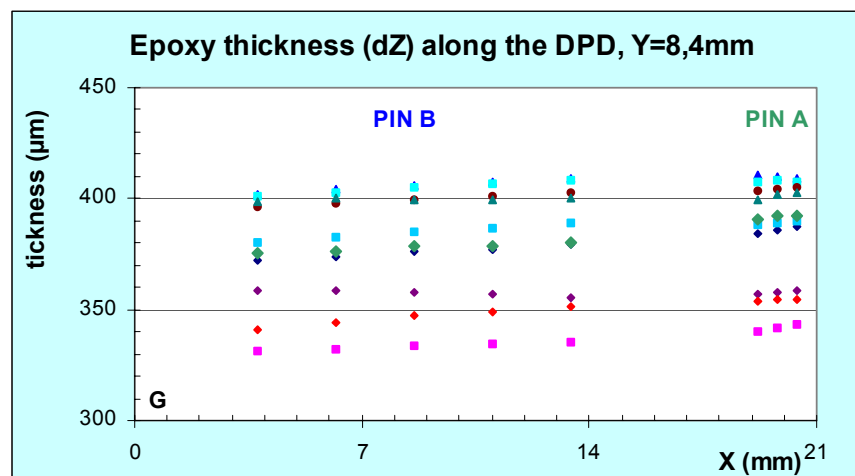


Fig . 7: Thickness of the epoxy along the DPDs

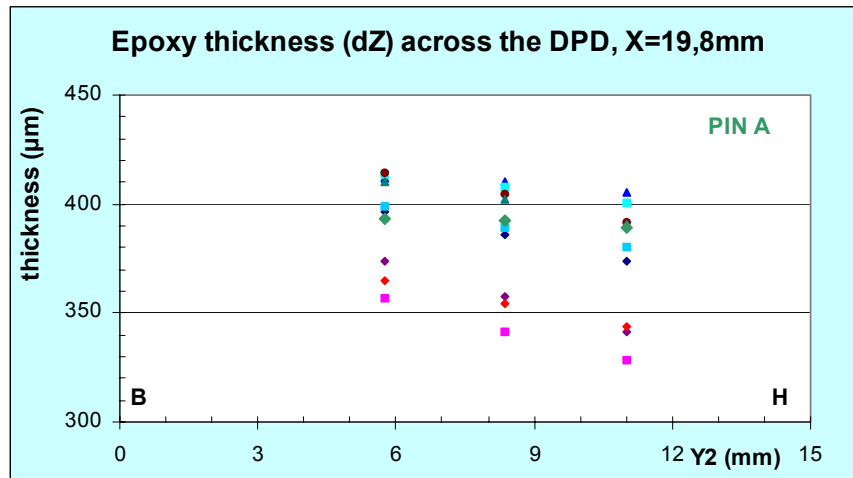


Fig . 8: Thickness of the epoxy across the DPDs, PIN A

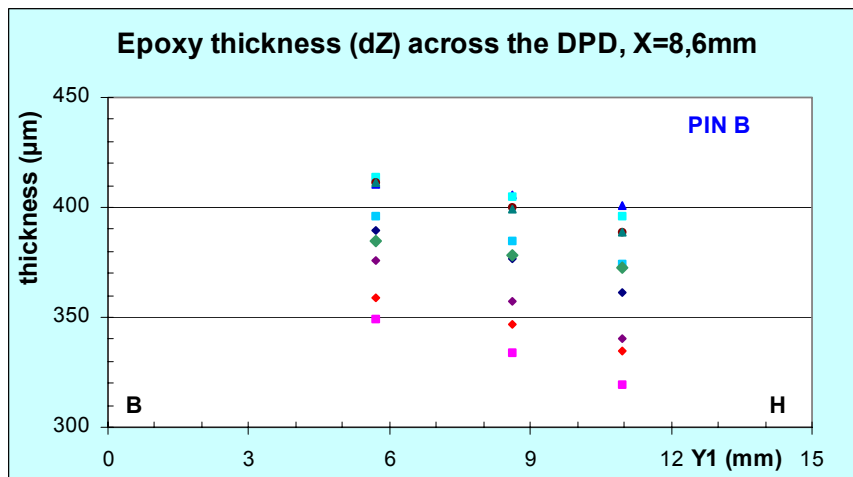


Fig . 9: Thickness of the epoxy across the DPDs, PIN B

We could see a systematic decrease of the epoxy thickness across the PIN A and B. At SERMA, section across a PIN diode of a DPS has been done and we have observed the ceramic high is not the same on each side contrary to what we thought. Two possibilities: either at the ceramic manufacturing or when polishing the epoxy.

We see no systematic effect on the epoxy thickness along the DPDs.

3.1.3 Visual inspection

We have done visual inspection of the DPDs and we have also observed the concavities at the level of the edge opposite to the pin connectors side we have check the deep of a concavity and found also about 50µm (see fig. 10).

We have observed:

- a scratch on one DPD of about 8mm long (but this scratch could be done as well at the manufacturer as at NRL or at Saclay) .
- Glue residue on the edge of the ceramic up to 0.1µm
- Dirt surround of the ceramic (glue residue!)

Using to the binocular microscope we have also observed:

- At the base of the pin connectors: mark and/or incrustation, white residue (see fig. 11).
- Into the epoxy layer a bubble (see fig. 12).

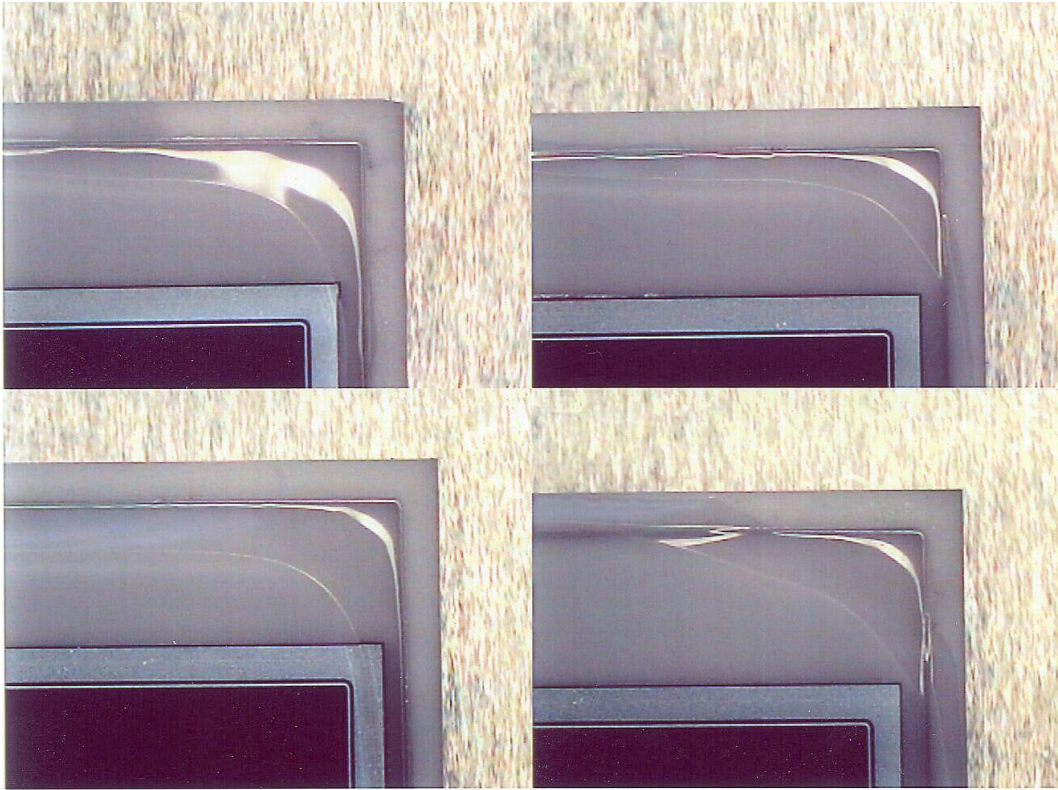


Fig . 10: View of concavities (Hamamatsu picture)

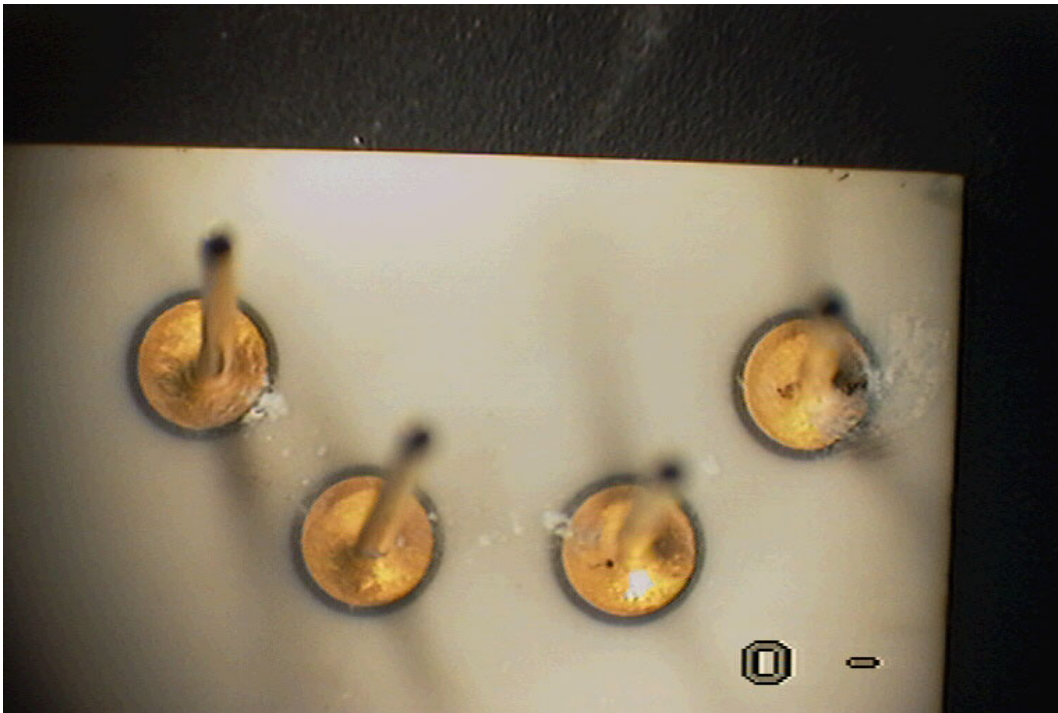


Fig . 11: mark, incrustation and white residue



Fig . 12: Bubble into the epoxy layer at the edge of PIN B

3.2 Electrical test

The process is described in the procedure (SED-GLAST-Y-5300-128-PA). We have measured at the same time the capacitance and the Dark Current. The figure 13 and 14 show the experimental setup.

The measurements of the DPDs are done PIN by PIN:

- the Dark Current is measured with a Pico-ampere meter, it needs more than 8mn to reach the asymptotic stabilization.
- the capacitance is given by an analyzer network at 1MHz.

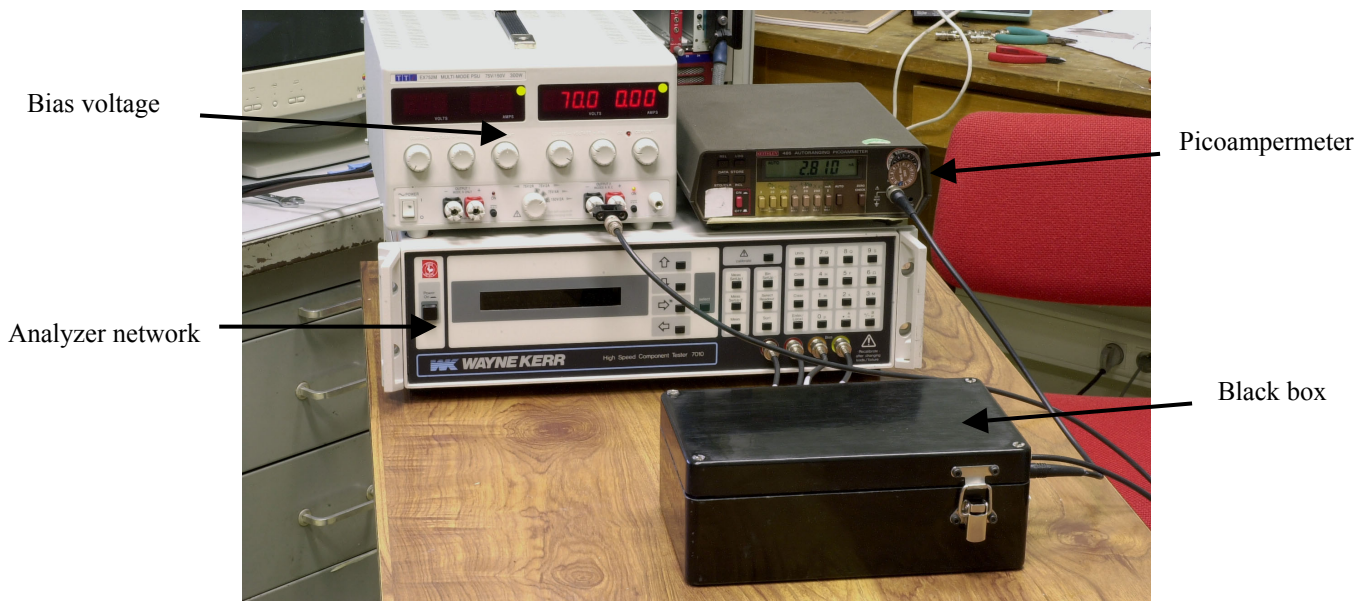


Fig . 13: Setup of the electrical measurements

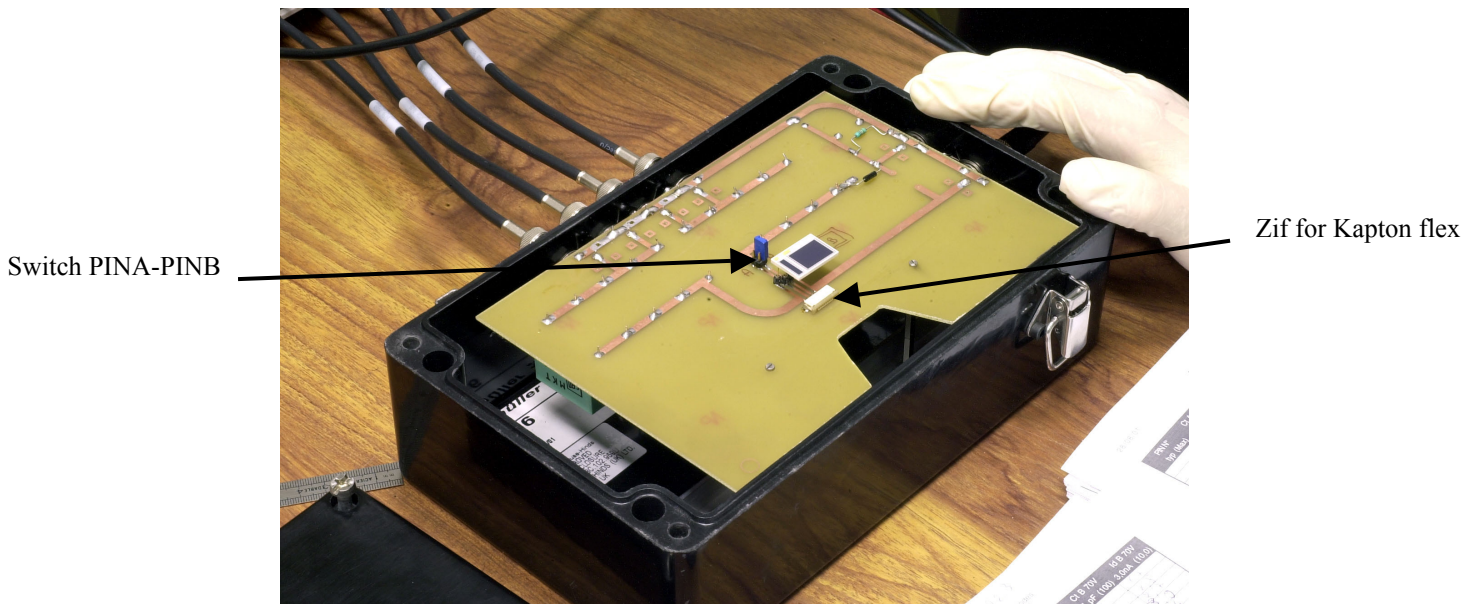


Fig . 14: Inside of the black box

The results are summarized in the table 4 and the 2 figure 15 and 16.

The air conditioning of the laboratory was defective so there are important temperature fluctuations, but the humidity was well controlled (40+/-5%). Hamamatsu measurement have been done at 25°C , so we are in good agreement when our lab is at 25°C when not, our results oscillate around Hamamatsu results with the temperature.

Our capacitance results are systematically a little bit higher than Hamamatsu ones (1.6pF and 1.2pF respectively for PIN A and B).

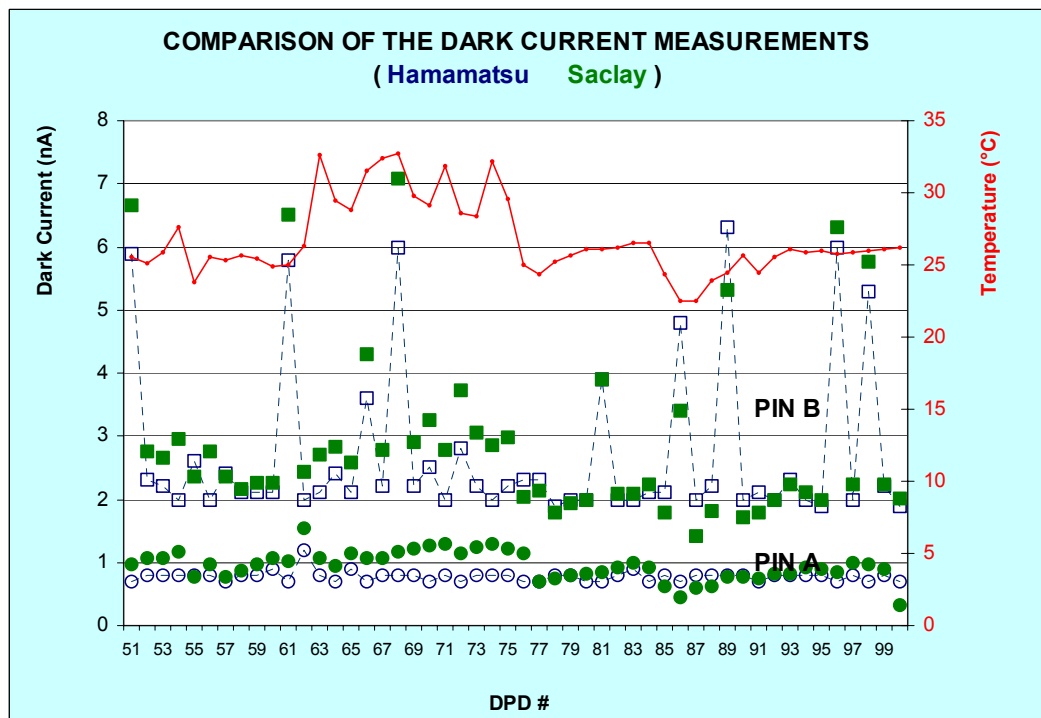


Fig . 15: Dark Current graphs of the NRL DPDs

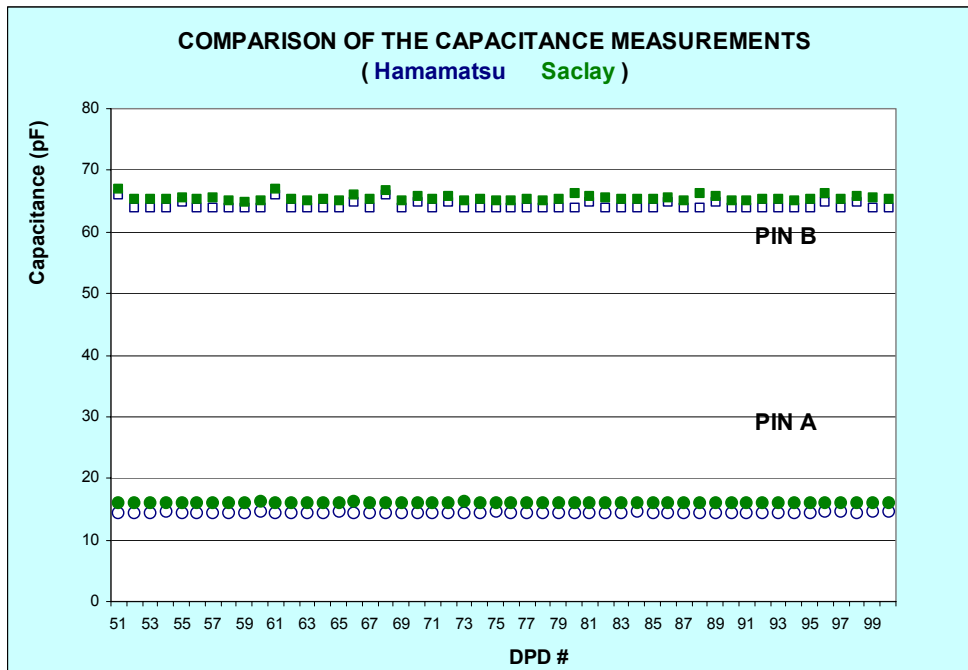


Fig . 16: Capacitance graphs of the NRL DPDS

Typ (Max)	PIN A : 10 pF(15); 1 nA (3)				PIN B : 65 pF(100); 3 nA (10)				T (°C)
	Hamamatsu		CEA		Hamamatsu		CEA		
	Cap.	D.C.	Cap.	D.C.	Cap.	D.C.	Cap.	D.C.	
mean	14,45	0,78	16,09	0,95	64,30	2,71	65,54	2,93	26,72
min	14,40	0,70	15,99	0,33	64,00	1,90	65,00	1,42	22,50
max	14,70	1,20	16,20	1,54	66,00	6,30	67,10	7,09	32,70
rms	0,12	0,08	0,04	0,23	0,58	1,30	0,49	1,39	2,59

Table 4: Summaries of the electrical measurements of the NRL DPDS.

4 Test on the 200 CEA DPDS

4.1 Mechanical test

4.1.1 Dimensions

We have done systematic measurements only for the thickness (e) and the position of the pin #4. We have measured the length (L) and the width (l) only on 60 over the 200 DPDS. At the moment no systematic visual inspection has been done.

	Sizes			Position of pin #4	
	L	l	e	a4	b4
Specif. (mm)	22,30	15,00	1,78	1,75	2,55
Average (mm)	22,32	15,01	1,83	1,72	2,58
Min (mm)	22,29	14,98	1,73	1,63	2,41
Max (mm)	22,39	15,05	1,98	1,88	2,76
max-min (μm)	100	70	250	253	356
rms (μm)	18	15	37	60	66

Table 5: Summaries of the mechanical measurements of the 200 CEA DPDS.

The position of the output pin has been measured with a more sophisticated apparatus associated to a computer (Optical profile meter).

The results of table 5 are similar to those obtained on the NRL ones (see table 2) apart for the thickness (max-min 100µm to 250µm), so we have done complementary measurement, see next section.

4.1.2 Trapezoid shape

We could observe an increase of the thickness max-min value. As we have used the gauge on all the width of the DPD, we have redone the measurement on the edges (opposite to the pin connectors sides) on all the DPDs with a thickness greater than 1.83mm plus some “good” ones.

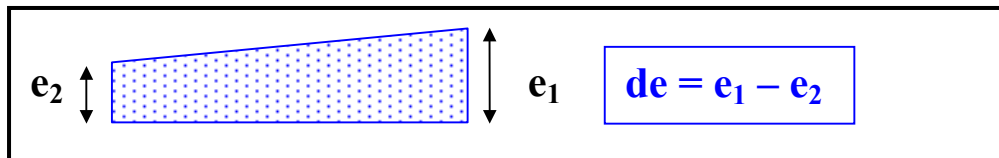


Fig . 17: Measurements schema

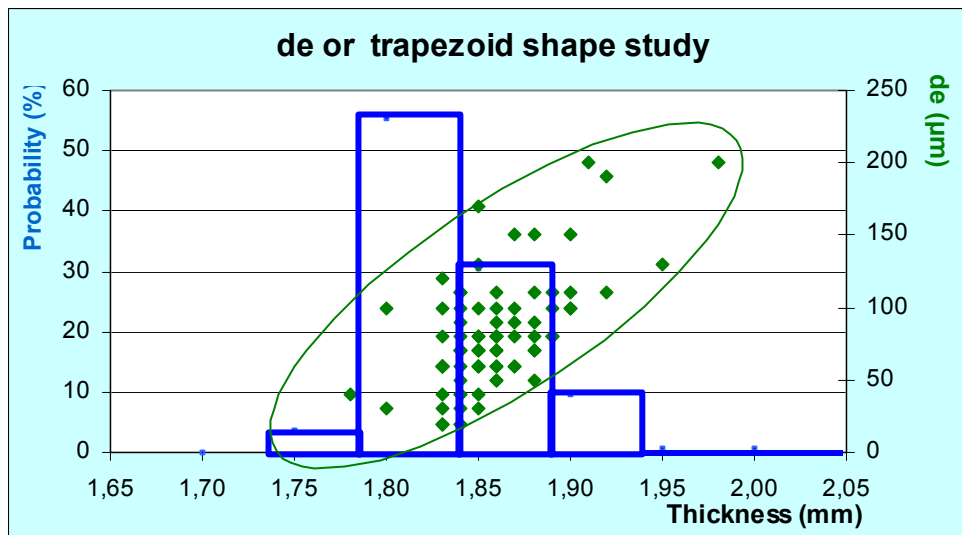


Fig . 18: Histogram of the thickness and de versus e_1 correlation

We remind there are a few points under $e_1=1.84$ mm in the plot e_1 versus de , because we have measured essentially the DPDs with thickness greater than 1.83mm and only some with typical value.

We could see a good correlation between the thickness and thickness difference, we know there is ceramic defect (see section 3.1.2) nevertheless we to look if there is also an excess of epoxy in the case of very large thickness difference.

4.2 Electrical test

We have upgraded the procedure taking into account the experience of the NRL DPDs measurements. So we have decoupled the capacitance and Dark Current measurements. The Capacitance measurements being instantaneous while the D.C. measurements take about 10mn (see figure 19).

We are studying a new setup to measure around 20 DPDs simultaneously.

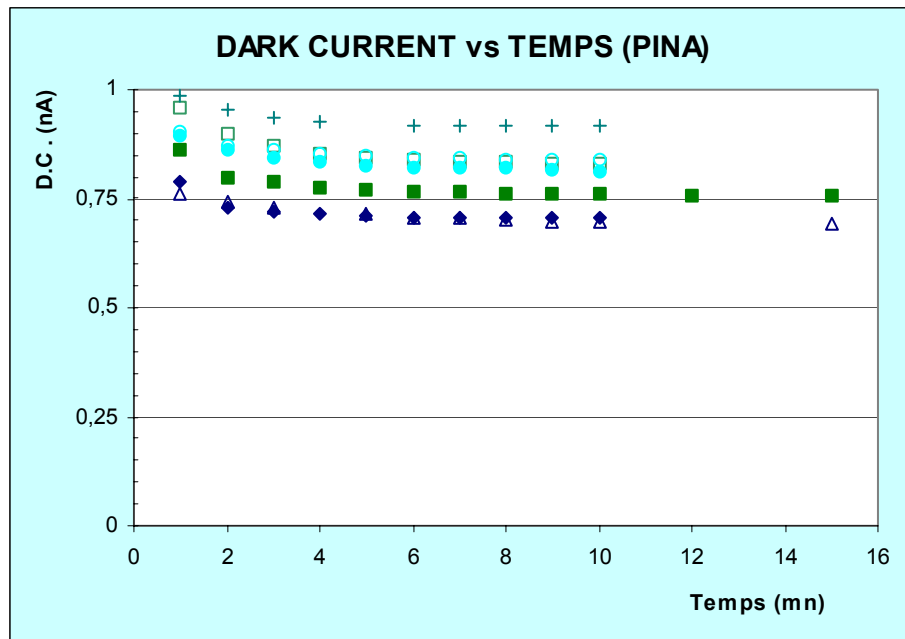


Fig . 19: Asymptotic stabilization of Dark Current versus time for different DPDs

The laboratory has air conditioning so there are not important temperature fluctuations, but the humidity was not controlled ($45 \pm 12\%$). At one time we have observed fluctuation of the difference between our and Hamamatsu measurement. The difference could be explained by the laboratory temperature which was $20.6 \pm 0.6^\circ\text{C}$ but the fluctuation was not this time due to temperature fluctuation. We have observed a correlation between this fluctuation with the humidity but in a second time the humidity fluctuation persist and not the dark current fluctuations (see figure 20 and 21), we have no explanation at the moment, only leads like condensation effect. The correlation could seem to be greater for the smaller PIN A in relative value, but it is the same in absolute value (same scale for both graphs)

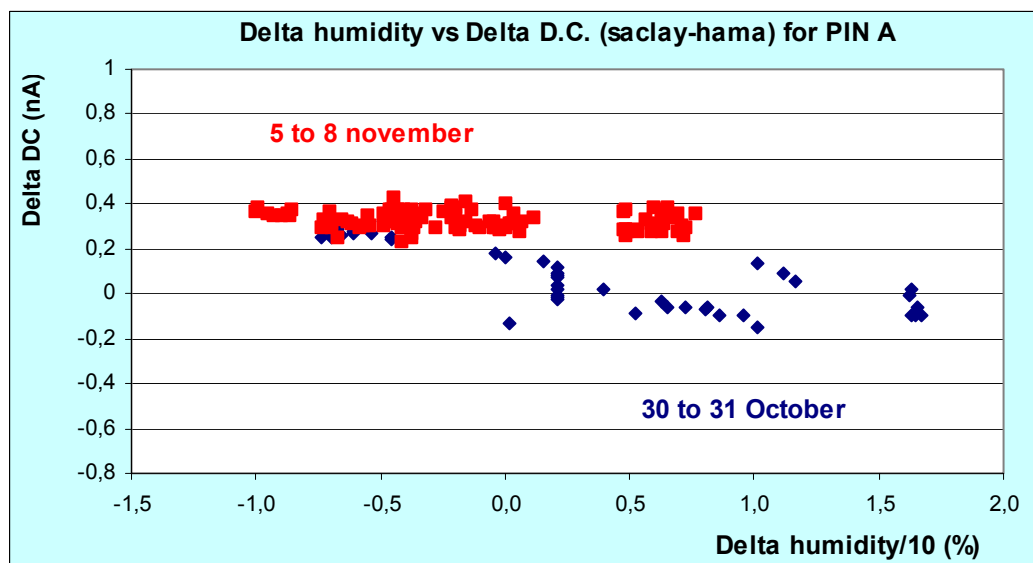


Fig . 20: Correlation between humidity fluctuation and D.C. fluctuation for PIN A

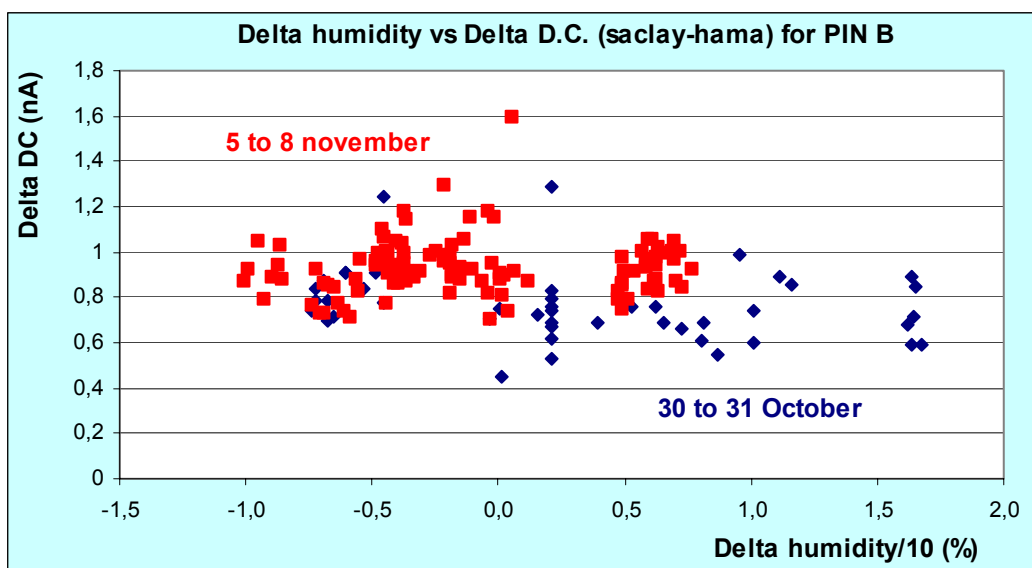


Fig . 21: Correlation between humidity fluctuation and D.C. fluctuation for PIN B

The results are summarized in the table 6 and the 2 figure 22 and 23:

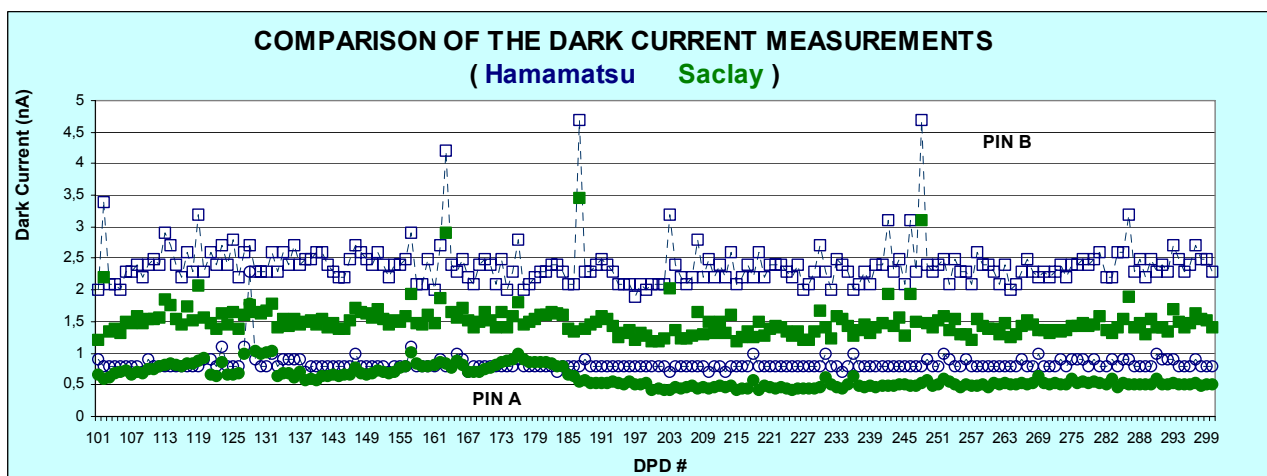


Fig . 22: Dark current graphs of the CEA DPDs

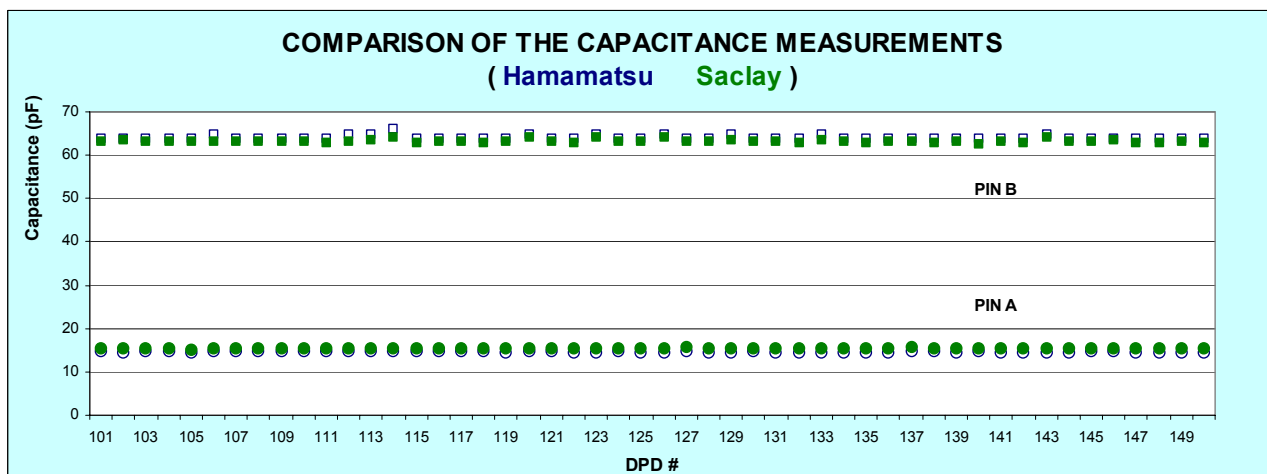


Fig . 23: Capacitance graphs of the CEA DPDs

Typ (Max)	PIN A : 10 pF(15); 1 nA (3)				PIN B : 65 pF(100); 3 nA (10)			
	Hamamatsu		Saclay		Hamamatsu		Saclay	
	Cap.	D.C.	Cap.	D.C.	Cap.	D.C.	Cap.	D.C.
mean	14,48	0,83	15,01	0,62	64,13	2,40	62,88	1,51
min	14,40	0,70	14,61	0,42	63,00	1,90	62,08	1,19
max	14,90	2,30	15,78	1,78	66,00	4,70	64,28	3,45
rms	0,14	0,12	0,33	0,18	0,39	0,36	0,44	0,27

Table 6: Summaries of the electrical measurements of the NRL DPDs.

Our capacitance results are this time a little bit higher than Hamamatsu one for PIN A 0.6pF and a little bit smaller for PIN B 1.2pF.

We have to understand why the dark current measurements have been more stable since the 5 November.

5 Test with the Kapton Flex

To equip the VM2 Xtals we have welded kapton flex (CF-GLAST-N-5400-33-PM) on 34 DPDs (16 Xtals + 2 spares), we have done electrical measurements at different steps of the flex welding process.

We have received 2 lots of Kapton flex, the first one give bad result in term of parasitic dark current (see table 7).

Kapton Flex	PIN A		PIN B	
	(pF)	(nA)	(pF)	(nA)
Lot #1	1,03	0,344	1,05	0,614
Lot #1 baked	1,01	0,055	1,03	0,068
Lot #2 a	1,05	0,074	1,06	0,004
Lot #2 b	1,02	0,012	1,05	0,004

Table 6: Summaries of the electrical measurements on Kapton flex.

We have measured one flex from lot #1 as received, one after bake-out and two flexes from lot #2 (a, b) as received.

We have discover that the lot #1 has been badly prepared (not well cleaned and not baked). The dark current results show the importance of baking the flex to remove humidity (a factor 10).

We have used this first lot for the 8 first DPDs for tests, fortunately, before welding the society has cleaned then baked the flex.

So on the 8 first DPDs we have done measurements:

- DPD alone
- DPD with the flex welded
- DPD with the flex and varnish on the weld.

On the measurements perform on this 8 first welding we have observed not incidence on the dark current and we have extract the contribution of each element to the residual capacitance:

- Kapton flex 1,04+/-0,02pF
- Solder PIN A 1,12+/-0,05pF
- Solder PIN B 0,41+/-0,09pF
- Varnish PIN A 0,18+/-0,08pF
- Varnish PIN B 0,31+/-0,13pF

Total residual capacitance due to Kapton flex : 2.5+/-0.2 pF

Then we have ordered the welding of flex with the varnish (Solithane 113 from Thiokol, polyurethane) (Lot #2) on 26 new DPDs and we have done measurements:

- DPD alone
- DPD with the flex and varnish on the weld.

Then we have ordered the welding of flex with the varnish (Lot #2) on 30 new DPDs and we have redone the measurements.

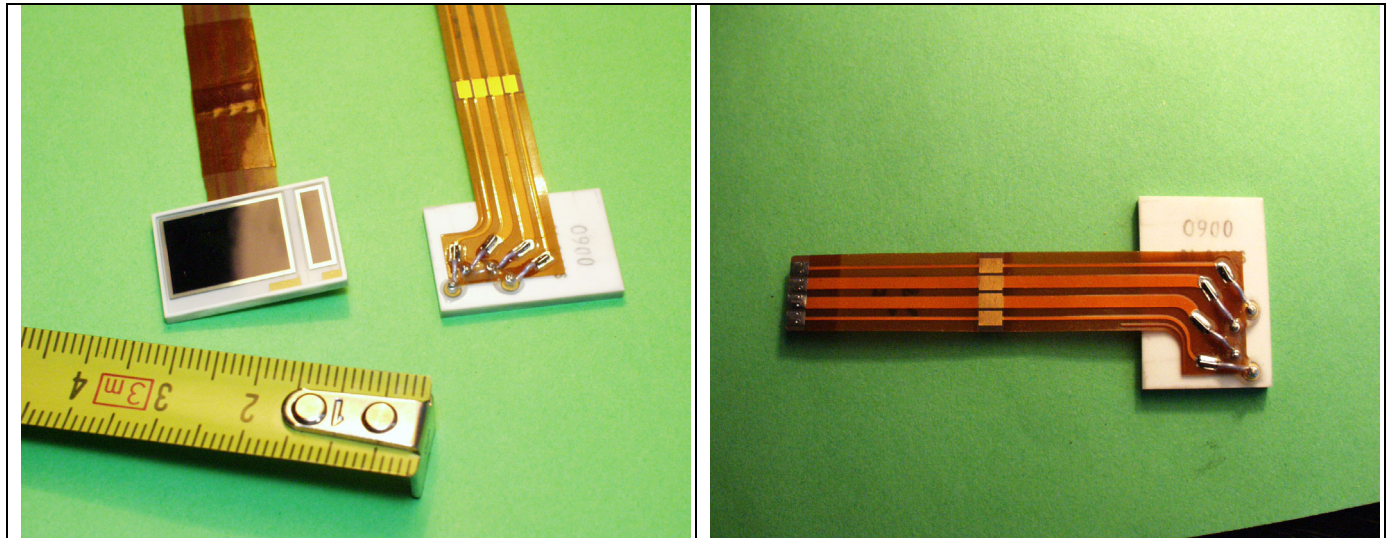


Fig . 24: Picture of the kapton flex welded on a DPD

The table 7 summarize the study of the Kapton flex incidence on capacitance:

	PIN A (pF)	PIN B (pF)
DPD alone (hamamatsu)	14,48+/-0,14	64,10+/-0,32
DPD alone (Saclay)	16,09+/-0,05	65,33+/-0,20
Flex alone	1,03+/-0,02	1,05+/-0,01
DPD+Flex (8DPDs)	18,24+/-0,06	66,84+/-0,16
DPD+Flex+varnish	18,43+/-0,06	67,07+/-0,25
DPD+Flex+varnish baked 3h at 105°C	18,35+/-0,04	67,08+/-0,18

Table 7: Summaries of the electrical measurements on the welding of Kapton flex.

We have tested the flex at the final length, that decrease the capacitance of 0.52pF. So the final capacitance will be of the order of 18pF and 66.5pF respectively for PIN A and B we will have to add the welding and varnish at the level of the PCB about 1.4pF (not negligible).

6 Conclusion

We are in good agreement with Hamamatsu data for the Capacitance and dark current, even during our unstable experimental conditions (temperature, humidity...). Therefor sampling tests as acceptance tests seem to be sufficient. We have to do the same test with the sensitivity.

The question of the electrical test after welding the kapton flex stay open. since we have observed no problem on the 34 DPDs welded, we probably do not need systematic electrical measurements. Standard control of the solder could be sufficient. The decisive test will be the CDE test before insertion into the module structure.

About the mechanical test apart the problem of trapezoidal shape, we have results nicely in the specification tolerances (+/-0.2mm). For the acceptance test of the flight module if the trapezoidal shape

will be a concern , we could plan to measure the thickness of all DPD (not too difficult , nor too risky or needing too much time). Depending of the final gluing process for the Length and the width we could used a dedicated gauge during the gluing procedure.

About the visual inspection we have to question Hamamatsu about the residues we have observed.

Our philosophy is to meet Hamamatsu with our quality manager, after amassing knowledge about our custom DPD (both the technology evaluation and our electrical, mechanical and optical tests), to define a common policy which allowed us to well understand the different steps of manufacturing of the DPDs to better define the specification and the future qualification and acceptance tests.